9.0 BASELINE ECOLOGICAL RISK ASSESSMENT SUMMARY

This section summarizes the baseline ecological risk assessment (BERA) for aquatic and aquatic-dependent species exposed to hazardous substances associated with the in-water Willamette River portion of the Portland Harbor Superfund site. The BERA is provided as Appendix G of this RI report. For the purpose of the BERA, the Willamette River is defined as all areas lower in water surface elevation than the ordinary high water mark (OHWM), including nearshore riparian zone areas not normally inundated by water. Ecological risks to terrestrial and upland species present in locations higher in elevation than the OHWM are being evaluated separately as part of the investigations of individual upland source areas under the oversight of the Oregon Department of Environmental Quality (DEQ) and are not evaluated as part of the BERA.

9.1 PURPOSE

The BERA evaluates potential threats to the environment at the time when the Portland Harbor RI was being conducted. As such, the BERA can be considered as describing ecological risks under the no action alternative of the feasibility study (FS) (EPA 1997b) absent any natural recovery in the river system. US Environmental Protection Agency (EPA) risk managers will use the results of the BERA, along with other relevant information included in this RI, to make decisions regarding remedial cleanup activities needed to protect the environment.

The specific overall objectives of the BERA are twofold:

1. Identify the risks posed by chemical contaminants to aquatic and aquatic-dependent ecological receptors associated with the Portland Harbor Study Area under baseline conditions.[1]
2. In the event that unacceptable ecological risks require remedial actions at Portland Harbor, provide information that risk managers can use to make remedial action decisions that are protective of ecological receptors.

Given the large number and wide variety of historical and present-day contaminant sources; the multitude of chemicals and hazardous substances released; the differences in the composition, volume, and mass of hazardous substances released from the various sources; and the multiple locations within and outside of the Study Area from which contaminants have been released, some contaminants have elevated concentrations throughout much if not all of the Study Area while many more contaminants are only elevated in sections of the StudyArea. This is reflected in the distribution and variability in the number of contaminants posing potentially unacceptable risks[2] in any specific

[1] Baseline conditions are the conditions represented by the BERA dataset, which is presented in Attachment 4 of the BERA in Appendix G, includes samples collected between June 2002 and November 2007.

[2] The phrase "contaminant posing potentially unacceptable risk" is used throughout this BERA instead of the more commonly used phrase "contaminant of (ecological) concern" (COC). Within various EPA guidance documents,

section of the Study Area, as well as the areal extent and magnitude of ecological risks from exposure to each hazardous substance.

9.2 ECOLOGY

The numerous aquatic and aquatic-dependent organisms that use the lower Willamette River can be divided into the following general groups: invertebrates, fishes, birds, mammals, amphibians, reptiles, and aquatic plants. All organisms present within the Study Area contribute to the ecological functioning of the river. Riverine invertebrates are predominantly benthic (i.e., living in or associated with river bottom substrates), using substrates such as fine-grained sediment, gravel and cobble, plant roots, and large woody debris. The benthic invertebrate community within the lower Willamette River is dominated by small benthic organisms, many of which feed on organic material imported from upstream areas.

The Willamette River is an important migration corridor for anadromous fishes, including Pacific lamprey and multiple salmon species, and provides habitat for approximately 50 resident fish species. Fish present in the river can be grouped into four major feeding guilds: omnivores/herbivores, invertivores, piscivores, and detritivores. Over 20 commonly occurring aquatic-dependent bird species use habitats and feed on aquatic species within the Study Area. The trophic representation of these birds is broad and includes herbivores, carnivores and omnivores, sediment-probing invertivores and omnivores, and piscivores. Seven aquatic or semi-aquatic mammals use or may use the river within the Study Area, including herbivores, omnivores, and piscivores.

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the phrases chemical of concern and contaminant of concern have at least six different definitions, making them somewhat imprecise terms. The contaminants posing potentially unacceptable risk at the end of the BERA are forwarded into the FS. It is the responsibility of the EPA risk manager to ultimately define the unacceptable ecological risks, which may become a basis for remedial actions to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site.

9.3 ECOLOGICAL RISK ASSESSMENT PROCEDURE

Procedures used in the BERA to evaluate the nature, severity, and areal extent of risks to ecological receptors in Portland Harbor were based on the guidance provided in the 8-step, iterative approach to ecological risk assessment (ERA) described in the EPA (1997b) *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final*. The 8 steps identified in this guidance are as follows:

1. Screening Level Problem Formulation and Ecological Effects Evaluation 2. Screening Level Preliminary Exposure Estimate and Risk Calculation	Screening-level ERA (SLERA)
3. Baseline Risk Assessment Problem Formulation 4. Study Design and Data Quality Objectives 5. Field Verification of Sampling Design 6. Site Investigation and Analysis of Exposure and Effects 7. Risk Characterization	BERA
8. Risk Management	Risk management

No guidance document, no matter how detailed, can describe the procedures needed to fully evaluate ecological risks at a site as complex as Portland Harbor. In order to accommodate the needs of this BERA, numerous Portland Harbor site-specific ERA procedures, methodologies, memoranda, and intermediate data reports and analyses have been developed and presented in documents prepared by the LWG in collaboration with and oversight of EPA and its federal, state, and tribal partners. Among these documents are the *Portland Harbor Remedial Investigation/Feasibility Study (RI/FS) Programmatic Work Plan* (Integral, Windward, Kennedy/Jenks, and GSI 2004), the draft *Portland Harbor RI/FS, Ecological Preliminary Risk Evaluation* (Windward 2005a), and the *Problem Formulation for the Baseline Ecological Risk Assessment at the Portland Harbor Site* (EPA 2008b).

9.4 CONTAMINANT AND TOXICITY DATA

The BERA dataset is a subset of the complete RI dataset and includes only those samples relevant to ecological exposure pathways. It does not contain sediment data from a depth greater than 30.5 centimeters (cm), or 12 inches (in.), below the sediment surface; nor does it include transition zone water (TZW) (i.e., sediment porewater that is composed of some percentage of both groundwater and surface water) collected greater than 38 cm (15 in.) below the sediment surface. The deeper sediment and TZW samples were excluded from the BERA exposure assessment because the likelihood that any species present in Portland Harbor comes into contact with or ingests such material is extremely low.

Contaminant data available for use in the BERA were collected during three rounds of sampling. Round 1 sampling, which focused on the collection of biota (tissue) samples, was conducted in 2002. Round 2 sampling began with multiple field efforts in 2004 and focused on the characterization of surface and subsurface sediment quality. Round 3 sampling occurred between 2006 and early 2008 and included the collection of surface water, biota, sediment upstream and downstream of the Study Area, suspended sediment (in-river sediment traps), and stormwater samples. Round 3 sampling also filled data gaps related to site characterization, ecological and human health risks, upriver background contaminant concentrations, and the FS.

As a result of the systematic approach that was used to generate Study Area data, the Portland Harbor BERA is supported by an extensive, high-quality database that features the concentrations of numerous chemicals in multiple environmental media types (i.e., sediment, water, bird eggs, and tissues from multiple fish and invertebrate species). In addition to this chemical dataset, a sizable number of sediment toxicity test results, which directly measured the effect of sediment constituents on the survival and growth of two benthic species were available. The numbers of samples in the BERA dataset are summarized in Table 9-1.

Table 9-1. Numbers of Samples Chemically Analyzed During the Portland Harbor BERA

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Location	Sediment	Sediment Toxicity Tests	Fish and Invertebrate Tissue	Bird Eggs	Surface Water	Transition Zone Water
Study Area (RM 1.9 – RM 11.8)	1,469	269	315	5	313	192
Downstream reach (RM 0 – RM 1.9)	21	0	5	0	0	0
Multnomah Channel	7	0	0	0	0	0
Downtown reach (RM 11.8 – RM 15.3)	17	2	6	0	0	0
Upstream (RM 15.3 – RM 28.4)	22	22	18	5	0	0

BERA – baseline ecological risk assessment
RM – river mile

In addition, a study was conducted to address the question of whether the use of surrogate species in the risk assessment would be protective of lamprey ammocoetes. The study evaluated the acute toxicity of six chemicals representing six different toxic modes of action (Andersen et al. 2010). Results indicated that the use of surrogates was protective of lamprey at this life stage.

9.5 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT FINDINGS

The screening level ecological risk assessment (SLERA), which encompass Steps 1 and 2 of the 8-step process described above, identified numerous contaminants of potential concern (COPCs) whose concentrations exceeded conservative screening-level effect thresholds in sediment, water, tissue, and ingested dietary doses. The possibility of ecological risks from hazardous substances within Portland Harbor could not be discounted based on the SLERA results; so, in accordance with EPA ecological risk assessment (ERA) policy and guidance, the more comprehensive baseline ecological risk evaluations described in the BERA were initiated.

9.6 BERA PROBLEM FORMULATION

According to EPA (1997b) guidance, a BERA problem formulation (Step 3 of the 8-step EPA ERA process) generally consists of the following five tasks:

- Refinement of the preliminary list of COPCs for the site
- Further characterization of the potential ecological effects of COPCs on Study Area receptors
- Review and refinement of information on the fate and transport of COPCs, on potential exposure pathways, and on the receptors potentially at risk
- Selection of assessment endpoints (environmental values to be protected)
- Development of a conceptual site model (CSM) with testable hypotheses (or risk questions) that the BERA will address

The products of the problem formulation are used to select measurement endpoints (what is actually measured at a site) and develop the ERA work plan and sampling and analysis plans (SAPs) for the Study Area in Step 4 of EPA's ERA process. In practice, Steps 3 and 4 of the 8-step EPA ERA process are often, as was the case for Portland Harbor, performed concurrently.

9.6.1 Identification of COPCs

The refined screen, which resulted in the final COPC list evaluated in the BERA, is presented in the BERA (Appendix G). Table 9-2 presents the number of COPCs carried forward from the refined screen to the risk characterization step for each environmental medium evaluated.

Table 9-2. Number of COPCs Evaluated in the BERA

Medium or Diet	No. of COPCs	No. of Chemicals without Screening-Level TRVs
Sediment	67	106
Invertebrate tissue	18	23
Fish tissue	16	8
Fish dietary dose	9	11
Bird dietary dose	23	19
Mammal dietary dose	12	11
Bird egg tissue	5	0
Surface water	14	19
TZW	58	14

BERA – baseline ecological risk assessment
COPC – contaminant of potential concern
TRV – toxicity reference value
TZW – transition zone water

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Table 9-2 also lists the number of chemicals within each medium for which screening-level or refined screen toxicity reference values (TRVs) could not be identified or derived. Risks associated with these chemicals were evaluated if alternative methods were available to derive TRVs in the BERA; otherwise, risks from these chemicals could not be quantified. Unquantified ecological risks from contaminants without baseline TRVs are likely the primary source of uncertainty in the BERA that could lead to underestimating ecological risks within Portland Harbor because most other types of uncertainty are handled by making conservative assumptions, which tends to build a margin of safety into ecological risk estimates.

The types or groups of contaminants identified as COPCs in the BERA are summarized in Table 9-3. Screening resulted in the identification of a combined 104 COPCs for benthic invertebrates across four media types (i.e., sediment, invertebrate tissue, surface water, and TZW). A combined 74 fish COPCs were identified when the results of the screening of all fish species analyzed were compiled, based on summing the COPCs across all media and for the dietary line of evidence (LOE). Twenty-three COPCs were identified for birds through two LOEs, and twelve COPCs were identified for mammals based on one LOE. Finally, 64 COPCs were identified for amphibians and aquatic plants through two LOEs. More detailed information regarding the final COPC list for the various receptors is presented in the BERA (Appendix G).

Table 9-3. COPCs Forwarded to the BERA after Screening

Receptor Group	Media Evaluated	Number of COPCs	COPCs
Benthic invertebrates, bivalves, decapods	Surface water, TZW, sediment, tissue	104	20 metals, 2 butyltins, 21 individual PAHs or PAH sums, 4 phthalates, 12 SVOCs, 6 phenols, 16 pesticide or pesticide sums, total PCBs, 2,3,7,8-TCDD (dioxin), 16 VOCs, 3 total TPH fractions, cyanide, perchlorate
Fish	Surface water, TZW, sediment, diet, tissue	74	19 metals, 4 butyltins, 17 individual PAHs or PAH sums, BEHP, 3 SVOCs, total PCBs, dioxin TEQ, total TEQ, 7 pesticide or pesticide sums, 18 VOCs, cyanide, perchlorate
Birds and mammals	Diet (birds and mammals), bird eggs	23 (birds) 12 (mammals)	11 metals, 3 individual PAHs or PAH sums, 2 phthalates, total PCBs, dioxin TEQ, PCB TEQ, total TEQ, 3 pesticide or pesticide sums
Aquatic plants, amphibians	Surface water, TZW	64	15 metals, monobutyltin, 16 individual PAHs, BEHP, 3 SVOCs, total PCBs, 6 pesticide or pesticide sums, 18 VOCs, gasoline-range hydrocarbons, cyanide, perchlorate

BEHP – bis(2-ethylhexyl) phthalate
BERA – baseline ecological risk assessment
COPC – contaminant of potential concern
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TCDD – tetrachlorodibenzo-*p*-dioxin
TEQ – toxic equivalent
TPH – total petroleum hydrocarbons
TZW – transition zone water
VOC – volatile organic compound

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9.6.2 Ecological Effects Characterization

Ecological effects characterization within the BERA problem formulation resulted in the final list of TRVs and sediment quality values (SQVs) for the various environmental media and samples evaluated. TRVs and SQVs are contaminant concentrations in media (i.e., sediment, water, tissue, or diet), which, if not exceeded, describe contaminant concentrations considered to pose no or only acceptable levels of ecological risk.

A floating percentile model (FPM) and logistic regression model (LRM) were both used to evaluate site-specific synoptic sediment toxicity chemistry data to develop SQVs that provide relatively reliable predictions of sediment toxicity test results at 293 sediment sampling locations for which sediment toxicity tests were conducted (269 sampling locations in the Study Area and 24 sampling locations in the lower Willamette River upstream from the Study Area). The SQVs were then used to predict sediment toxicity at Portland Harbor sediment sampling locations for which sediment toxicity tests were not conducted.

The tissue residue approach presented in the BERA is used to derive contaminant concentrations in fish and aquatic invertebrate tissue, which, if exceeded, would define tissue contaminant concentrations posing potentially unacceptable ecological risks. Although screening-level ecological risk benchmarks for contaminants in aquatic life tissue have been available for some time, the BERA represents perhaps the first effort to derive numerous baseline tissue TRVs.

The remaining TRVs used in the BERA were taken from either existing compendia of environmental quality guidelines or directly from the original scientific literature. The basis for selection of each TRV is presented in the BERA.

9.6.3 COPC Fate and Transport, Exposure Pathways, and Receptors at Risk

Contaminant sources and distribution within Portland Harbor and their environmental fate and transport (Sections 4, 5, and 6, respectively, of this RI), as well as exposure pathways and the identification of ecological receptors potentially at risk, had largely been defined prior to the development of the BERA problem formulation (EPA 2008b). Therefore, this stage of the problem formulation focused on identifying a subset of species for which ecological risks would be evaluated in the BERA.

Given that Portland Harbor is inhabited by hundreds if not thousands of species, the majority of which are lower-trophic-level species, such as algae and benthic invertebrates, it is not feasible to quantify risks to every species within the Study Area. The primary selection criteria for ecological receptors were: 1) that they represent the feeding guilds present at Portland Harbor; 2) that the receptor use the same habitat as other similar species; 3) that the receptor be susceptible to contaminants; and 4) that the receptor be ecologically, culturally, or economically significant. The term feeding guild refers to a group of species that share similar feeding strategies or diets, thus, resulting in a similar potential for contaminant exposure as other members of the guild.

9.6.4 Assessment Endpoint Selection

Perhaps the most important planning step of the entire BERA is the development of the assessment endpoints, risk questions, measurement endpoints, and lines of evidence (LOEs) to be assessed in a BERA. This is because combined, they establish the goals, breadth, and focus of the BERA. Brief definitions of the above four terms are as follows:

Assessment endpoints – explicit expressions of environmental values to be protected

Risk questions – proposed or suspected relationships between assessment endpoints and their predicted responses when exposed to contaminants

Measurement endpoints – measurable ecological characteristics, either measures of exposure or measures of ecological effect that are related to the valued characteristics chosen as assessment endpoints

Line of evidence – a set of data and associated analyses that can be used, either alone or in combination with other LOEs, to estimate ecological risks

For each assessment endpoint, risk questions and testable hypotheses are developed. Risk questions provide the basis for defining measurement endpoints that are evaluated with information collected during studies designed and performed as part of this RI. Each measurement endpoint is evaluated with one or more LOEs.

The Portland Harbor BERA evaluates 13 assessment endpoints. Twelve of the thirteen assessment endpoints take the form of “survival, growth, and reproduction of” a group of species that share a habitat, taxonomic category, or feeding guild.

The 12 assessment endpoints with the form “survival, growth, and reproduction of….” are:

- Aquatic plants
- Benthic macroinvertebrates
- Bivalves
- Decapods
- Invertivorous fish
- Omnivorous fish
- Piscivorous fish
- Amphibians
- Piscivorous birds
- Omnivorous birds
- Invertivorous birds

- Aquatic-dependent mammals

The 13th assessment endpoint is:

- Survival and growth of detritivorous fish (Pacific lamprey ammocoetes)

Reproduction is not evaluated for Pacific lamprey ammocoetes because this is not the reproducing life stage of the lamprey.

The full list of 24 target ecological receptors, 31 measurement endpoints, and 55 LOEs evaluated is presented in Attachment 2 of the BERA.

9.6.5 Conceptual Site Model Development

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The last step of the problem formulation, the development of the CSM, was also largely completed prior to the commencement of work on the BERA problem formulation (EPA 2008b). A CSM describes relationships between contaminants and the resources potentially affected by their release.

The routes of exposure are the means by which contaminants are transferred from a contaminated medium to an ecological receptor. The most significant pathways by which ecological receptors may be exposed to Portland Harbor COPCs are:

- **Aquatic plants –** Root uptake; direct contact with sediment, surface water, and TZW
- **Benthic invertebrates –** Direct contact with sediment, surface water, and TZW; ingestion of sediment and food
- **Fish –** Direct contact with sediment, surface water, and TZW; ingestion of sediment and food
- **Birds and mammals –** Ingestion of soil, sediment, and food
- **Amphibians –** Direct contact with surface water and TZW; ingestion of sediment and food

9.7 STUDY DESIGN AND DATA QUALITY OBJECTIVE PROCESS

The study design and data quality objectives process, Step 4 of the 8-step process described above, describes the individual sediment, water, and biota sampling events that were carried out during the BERA. All of the sampling and chemical analyses performed to obtain the data used in the BERA followed procedures defined in the ERA work plan (Integral, Windward, Kennedy/Jenks, and GSI 2004) and the numerous SAPs for various tasks. The data management rules (including data reduction, data usability, and data quality) are described in detail in Appendix A of the RI.

The data quality objective (DQO) process used during the development of the BERA SAPs describes a series of planning steps that were employed to ensure that the type, quantity, and quality of environmental data collected for the BERA were adequate to support the intended uses of the data.

9.8 FIELD VERIFICATION OF SAMPLING DESIGN

Step 5 of the 8-step ERA process verifies that the selected assessment endpoints, testable hypotheses, exposure pathway model, measurement endpoints, and study design from Steps 3 and 4 are appropriate and implementable at the Study Area. By verifying the study design, alterations can be made to the study design and/or implementation if necessary. These changes ensure that the ERA meets its objectives.

The availability of radiotelemetry information on the movement of juvenile salmonids, smallmouth bass, and northern pikeminnow (Friesen 2005) in the Study Area allowed for the development of site-specific home range estimates for these species. Site-specific home range estimates for aquatic species are rare at Superfund sites, and the availability of such information for several target ecological receptors informed field sampling plans (FSPs) and also allowed for the definition of species-specific contaminant exposure concentrations for these species.

9.9 SITE INVESTIGATION AND ANALYSIS OF EXPOSURE AND EFFECTS

Information collected during the site investigation (Step 6 of the 8-step EPA ERA process) was used to characterize exposures and ecological effects. The site investigation included all of the field sampling and surveys that were conducted as part of the ERA. The site investigation and analysis of exposure and effects followed the ERA work plan (Integral, Windward, Kennedy/Jenks, and GSI 2004) and the numerous SAPs and FSPs developed and tested in Steps 4 and 5.

9.9.1 Ecological Exposure Assessment

To ensure conservatism (i.e., protectiveness) in the BERA, all COPCs are first evaluated on a sample-by-sample basis. The exposure of benthic invertebrates is assessed based on contaminant concentrations in individual samples of sediment, water, and TZW throughout the BERA, inasmuch as settled individuals of these species have little or no ability to move within the Study Area.

Because a sample-by-sample exposure area is not ecologically relevant for the mobile receptors evaluated in the BERA (i.e., fish, birds, and mammals), COPCs for mobile species are then evaluated at an exposure scale that is ecologically relevant for each specific receptor. The exposure area for mobile receptors is defined as the home range of each target ecological receptor evaluated. With the exception of the fish species for which site-specific movement and home range information was available, home ranges are derived from the published ecological literature. For dietary risks to fish and wildlife, exposure estimates are also determined for a diet consisting of multiple prey species using prey portions reported in the literature. Exposure concentrations are based both on contaminant concentrations quantified in the analytical laboratory (i.e., empirical concentrations) and, for some LOEs (i.e., the tissue-residue LOE and the dietary LOE for shorebirds), on predicted values.

9.9.2 Ecological Effects Assessment

The effects assessment involves two general approaches. For most ecological receptors, the effects of COPCs are assessed by comparing contaminant concentrations in each environmental medium with contaminant- and medium-specific TRVs or site-specific SQVs. Consistent with the problem formulation, for all receptors and receptor groups evaluated at the community or population level, lowest-observed-adverse-effect level (LOAEL) TRVs are used. No-observed-adverse-effect level (NOAEL) TRVs are used for receptors evaluated at the organism level (i.e., juvenile Chinook salmon, Pacific lamprey ammocoetes).

The second effects assessment approach uses sediment toxicity bioassays as a direct measure of the effects of sediment contaminant mixtures on the survival and biomass of benthic invertebrates in the laboratory. Two predictive models (the FPM and LRM) are used to develop site-specific SQVs. The goals of both models are to predict benthic toxicity for locations at which there were no measured toxicity data and to define site-specific SQVs based on associations between measured sediment chemistry and measured sediment toxicity.

9.10 RISK CHARACTERIZATION

Risk characterization (Step 7 of the EPA (1997b) 8-step ERA process) is the final phase of the BERA itself. During risk characterization, information from the exposure assessment and ecological effects assessment are combined into descriptions of the likelihood of unacceptable ecological risk to the assessment endpoints established in the problem formulation (Step 3 of the 8-step process). The risk characterization includes information on the contaminants posing potentially unacceptable risk, which ecological receptors are at risk, the media and exposure pathways in which contaminants posing potentially unacceptable risks are found, the magnitude of the risks, and the location(s) of risks within the Study Area.

In addition to the quantitative calculations performed to estimate risks, the risk characterization also discusses the level of agreement among the multiple LOEs used to assess risks to the assessment endpoints, the relative strengths and weaknesses of each LOE, the ecological significance of identified risks, and the uncertainties associated with the risk assessment conclusions.

Direct evidence of causality, if available, provides the strongest LOE for a site posing potentially unacceptable ecological risks. Sediment toxicity tests were performed to evaluate adverse effects of Portland Harbor sediment on survival and biomass (a combined survival and growth endpoint) of larvae of the aquatic insect *Chironomus dilutus* and juveniles of the amphipod *Hyalella azteca*. Results are summarized in Table 9-4. These toxicity tests demonstrate that the exposure of these animals to sediment from some locations within Portland Harbor resulted in increased mortality and/or reduced biomass of these two species within 10 to 28 days – a direct measure of sediment toxicity to benthic invertebrates within the Portland Harbor Study Area.

Table 9-4. Sediment Toxicity Test Results

Test	Level 0 (No Toxicity)	Level 1 (Low Toxicity)	Level 2 (Moderate Toxicity)	Level 3 (Severe Toxicity)
Chironomus survival	210 of 256	12 of 256	9 of 256	25 of 256
Chironomus biomass	190 of 256	24 of 256	7 of 256	35 of 256
Hyalella survival	224 of 256	15 of 256	2 of 256	15 of 256
Hyalella biomass	143 of 256	47 of 256	42 of 256	24 of 256

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The moderate and severe levels of toxicity are not randomly scattered throughout the Study Area. Instead, most samples and locations eliciting multiple instances of moderate and severe toxicity tend to be clustered in several areas, especially areas between RM 5.9 and RM 7.8 on the west side of the river. Other areas with "clusters" of benthic toxicity include:

- International Slip
- Between RM 3.7 and RM 4.2, west side of river
- Between RM 4.8 and RM 5.2, west side of river
- Willamette Cove
- Near the mouth of Swan Island Lagoon
- RM 8.7 to RM 8.8, west side of river

Other individual samples and locations exhibited toxicity to *Chironomus* and *Hyalella*. However, the above areas are those within the Study Area where the greatest toxicity was found. A weight-of-evidence analysis identified 17 benthic areas of concern (AOCs) within the Study Area. Combined, EPA estimated the above areas ~~can be estimated~~ to cover between 4% and 8% of the total surface area of sediment within the Study Area.[3]

[3] Estimates of the proportion of the Study Area eliciting moderate or severe toxicity to benthic invertebrates are made using geographic information system (GIS) models. Different GIS models make different extrapolations of

Contaminants found at elevated concentrations relative to SQVs in these areas are those most likely to be posing ecological risks to benthic invertebrates.

Most risk characterizations in the BERA are made using the hazard quotient (HQ). An HQ is calculated by dividing the exposure point concentration (EPC) by the selected TRV. HQs can also be comparisons of ingested dietary doses of contaminants with dietary TRVs or comparisons of measured COPC concentrations in prey of target ecological receptors with threshold tissue concentrations in prey species.

COPCs for which the HQ was ≥ 1.0 ~~are identified as contaminants posing potentially unacceptable risk~~ at the conclusion of the BERA are identified as contaminants posing potentially unacceptable risk. The potential for unacceptable risk becomes increasingly large as the HQ value increases, although the increase is not necessarily linear (e.g., an ~~sample~~ exposure area with an HQ = 2.0 does not necessarily have twice the risk of an ~~sample~~ exposure area with an HQ = 1.0 for the same LOE)[4].

The complete list of COPCs posing potentially unacceptable ecological risks to the BERA assessment endpoints, the exposure pathways by which COPCs pose potentially unacceptable risks, and sections of the BERA where additional details can be found regarding the magnitude of risks, risks to specific target ecological receptor species, and locations within the Study Area where risks are found are presented in Table 9-5.

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contaminated areas between sample locations of known levels of contamination or toxicity accounting for the range in the estimates of the percentage of the Study Area that elicits moderate or severe toxicity.

[4] Also, the HQ scale is not necessarily the same for different LOEs or COPCs. For example, the potentially unacceptable risks for two LOEs with HQ = 2 for the same COPC and exposure area are not necessarily the same, nor are the potentially unacceptable risks for two COPCs with HQ = 2 for the same LOE and expousre area.

Table 9-5. COPCs Posing Potentially Unacceptable Ecological Risks within the Portland Harbor Study Area

Assessment Endpoint	Exposure Pathway	COPCs with HQ ≥ 1.0	Section of the BERA with Additional Details
Aquatic plants, amphibians	Surface water	Benzo(a)anthracene, benzo(a)pyrene, BEHP, naphthalene, total DDx, total PCBs,[a] zinc	Sections 9-1 (amphibians) and 10-1 (aquatic plants)
	TZW	1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 2-methylnaphthalene, 4,4′-DDT, acenaphthene, anthracene, barium, benzo(a)anthracene, benzo(a)pyrene, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, copper, cyanide, ethylbenzene, fluorene, gasoline fraction (aliphatic) C4 – C6, gasoline fraction (aliphatic) C10 – C12, iron, isopropylbenzene, lead, magnesium, manganese, naphthalene, nickel, perchlorate, phenanthrene, potassium, sodium, toluene, total DDx, zinc	Sections 9-2 (amphibians) and 10-1 (aquatic plants)
Benthic invertebrates, bivalves, decapods	Sediment	2,4′-DDD, 2-methylnaphthalene, 4,4′-DDD, 4,4′-DDE, 4,4′-DDT, 4-methylphenol, acenaphthene, acenaphthylene, ammonia,[b] anthracene, Aroclor 1254,[c] arsenic,[c] benzo(a)anthracene, benzo(a)pyrene,[c] benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzyl alcohol, cadmium, carbazole, chlordane (cis and trans),[c] chromium, chrysene, cis-chlordane, copper, dibenzo(a,h)anthracene, dibenzofuran, dibutyl phthalate, dieldrin, diesel-range petroleum hydrocarbons, endrin, endrin ketone, fluoranthene, fluorene, gasoline-range hydrocarbons,[d] heptachlor epoxide,[c] indeno(1,2,3-cd)pyrene, lead, lindane (γ-HCH),[c] mercury, naphthalene,[c] nickel,[c] phenanthrene, phenol, pyrene, residual-range hydrocarbons,[e] silver, sulfide,[b] sum DDD, sum DDE, sum DDT, total chlordane,[c] total DDx, total endosulfan, total HPAH, total LPAH, total PAH, total PCBs, TBT, zinc,[c] β-HCH, δ-HCH	Sections 6-2 and 6-3
	Surface water	4,4′-DDT,[a] benzo(a)anthracene, benzo(a)pyrene, BEHP, ethylbenzene, naphthalene, total DDx, total PCBs,[a] trichloroethene, zinc	Section 6-5

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Table 9-5. COPCs Posing Potentially Unacceptable Ecological Risks within the Portland Harbor Study Area

Assessment Endpoint	Exposure Pathway	COPCs with HQ ≥ 1.0	Section of the BERA with Additional Details
	TZW	1,1-Dichloroethene, 1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2-methylnaphthalene, 4,4′-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) C4 – C6, gasoline fraction (aliphatic) C6 – C8, gasoline fraction (aliphatic) C10 – C12, gasoline fraction (aromatic) C8 – C10, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	Section 6-6
	Tissue	4,4′-DDD, arsenic, BEHP, copper, total DDx, total PCBs, TBT, zinc	Section 6-4
Fish	Surface water	4,4′-DDT,[a] benzo(a)anthracene, benzo(a)pyrene, BEHP, ethylbenzene, naphthalene, total DDx, total PCBs,[a] trichloroethene, zinc	Section 7-3
	TZW	1,1-Dichloroethene, 1,2,4-trimethylbenzene, 1,2-dichlorobenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, 2-methylnaphthalene, 4,4′-DDT, acenaphthene, anthracene, barium, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, beryllium, cadmium, carbon disulfide, chlorobenzene, chloroethane, chloroform, chrysene, cis-1,2-dichloroethene, cobalt, copper, cyanide, dibenzo(a,h)anthracene, dibenzofuran, ethylbenzene, fluoranthene, fluorene, gasoline fraction (aliphatic) C4 – C6, gasoline fraction (aliphatic) C6 – C8, gasoline fraction (aliphatic) C10 – C12, gasoline fraction (aromatic) C8 – C10, indeno(1,2,3-cd)pyrene, iron, isopropylbenzene, lead, m,p-xylene, magnesium, manganese, naphthalene, nickel, o-xylene, perchlorate, phenanthrene, potassium, pyrene, sodium, toluene, total DDx, total xylenes, trichloroethene, vanadium, zinc	Section 7-4
	Fish tissue	Antimony, BEHP, copper, lead, total DDx, total PCBs	Section 7-1
	Diet	Cadmium, copper, mercury, TBT	Section 7-2

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Table 9-5. COPCs Posing Potentially Unacceptable Ecological Risks within the Portland Harbor Study Area

Assessment Endpoint	Exposure Pathway	COPCs with HQ ≥ 1.0	Section of the BERA with Additional Details
Birds	Diet	Aldrin, benzo(a)pyrene, copper, dibutyl phthalate, lead, sum DDE, total DDx, total dioxin/furan TEQ, total PCBs, total PCB TEQ, total TEQ	Section 8-1
	Bird egg tissue	Total dioxin/furan TEQ, total PCBs, total PCB TEQ, total TEQ	Section 8-2
Mammals	Diet	Aluminum, lead, total dioxin/furan TEQ, total PCBs, total PCB TEQ, total TEQ	Section 8-1

[a] Identified as a COPC (HQ ≥ 1.0) when the AWQC TRV was adopted; not identified as a COPC (HQ < 1.0) when the alternative TRV was adopted. These chemicals are not included in the total counts of COPCs with potentially unacceptable ecological risk unless they were identified as a COPC for another LOE.

[b] Ammonia and sulfide in bulk sediment exceeded SLs but are not included in the total counts of COPCs with potentially unacceptable ecological risk.

[c] Identified as a COPC based on concentrations that exceeded the sediment PEC and/or PEL [BERA Section 6.3]; chemical was not identified as a COPC based on the FPM or LRM predicted toxicity LOE. These chemicals are not included in the total counts of COPCs with potentially unacceptable ecological risk unless they were identified as a COPC for another LOE (e.g., arsenic is identified as a COPC with potentially unacceptable risk for benthic invertebrates based on the tissue LOE and is, therefore, included in the total count of COPCs).

[d] Identified as a COPC based on concentrations that exceeded the TPH SQG (i.e., the chemical was not identified as a COPC for any other benthic sediment evaluation).

[e] Identified as a COPC based on concentrations that exceeded the TPH SQG; chemical was not included in the COPC counts if identified as a COPC based only on the TPH SQG exceedence.

AWQC – ambient water quality criteria
BEHP – bis(2-ethylhexyl) phthalate
COPC – chemical of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
FPM – floating percentile model
HCH – hexachlorocyclohexane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOE – line of evidence
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
LRM – logistic regression model
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
SL – screening level
SQG – sediment quality guideline
TBT – tributyltin
TEQ – toxic equivalent
total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TPH – total petroleum hydrocarbons
TRV – toxicity reference value
TZW – transition zone water

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Risk characterization would not be complete without mention of the LOEs for which no ecological risks are identified. Table 9-6 lists the LOEs for several assessment endpoints for which no ecological risks are identified.

Table 9-6. BERA LOEs for which No Potentially Unacceptable Ecological Risks Are Identified

Assessment Endpoint	Measurement Endpoint	Line of Evidence
Survival, growth, reproduction of benthic invertebrates	Benthic invertebrate tissue data compared to tissue TRVs	Field-collected epibenthic macroinvertebrate tissue concentration (from Hester-Dendy samplers) relative to tissue TRVs
Survival, growth, reproduction of bivalves	Sediment toxicity testing to empirically assess adverse effects	*Corbicula fluminea* survival in 28-day bioaccumulation test
Survival, growth, reproduction of omnivorous fish	Concentrations in surface water compared with water TRVs	
Survival and growth of detritivorous fish	Concentrations in surface water compared with water TRVs	

BERA – baseline ecological risk assessment
LOE – line of evidence
TRV – toxicity reference value

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9.11 ECOLOGICAL SIGNIFICANCE OF IDENTIFIED RISKS

The ecological significance of the identified risks is often determined by evaluating whether estimated risk will make a difference or be observed in light of other factors that are influencing the environment, such as habitat alteration. With the exception of species protected by law or regulation (threatened and endangered species) for which individual organisms are protected, EPA (1997b) guidance and policy state that BERAs should generally focus on the protection of local populations and communities of biota (e.g., the Study Area population of smallmouth bass, not the global population of smallmouth bass). Oregon's ERA guidance (DEQ 1998) defines a local population for a stream or river as follows, "For aquatic species in moving water such as streams and rivers (lotic habitats), the local population comprises all individuals of the endpoint species within the stream segment within the contaminated area."

Contaminant concentrations, which, if not exceeded, are protective of local populations and communities were largely estimated in this BERA by extrapolating from effects on individual organisms or groups of organisms using an line of evidence (LOE) approach. Hazard quotients greater than one (HQs $\geq$ 1) for a given LOE are considered to indicate potentially unacceptable risk to ecological receptors. For example, a HQ $\geq$ 1 might indicate the potential for reduced or impaired reproduction or recruitment of new individuals. Hazard quotients provide insight into the potential for adverse effects on organisms in the local population resulting from contaminant exposure. Any chemical of potential concern (COPC) with a HQ $\geq$ 1 in the final step of the risk characterization for at least one LOE in any location in the Study Area, or the risks of which could not be quantified in the BERA, was identified as a contaminant posing potentially unacceptable risk. Removal of contaminants with risks that could not be quantified from the list of contaminants posing potentially unacceptable risks resulted in the final list of contaminants forwarded for evaluation in the feasiblity study. The ecological significance of risk associated with each receptor-LOE-COPC combination posing potentially unacceptable risk was evaluated relative to the assessment endpoints to determine risk conclusions.

Ecological significance can be defined as the importance of an adverse effect on population, community, or ecosystem responses. Factors contributing to ecological significance considered in the BERA included the nature and magnitude of effects, the spatial and temporal extent of effects, uncertainties in the exposure assessment, uncertainties in the effects characterization, and concordance of the various LOEs used to assess risk to communities or populations. However, as there are no specific directions in EPA guidance (EPA 1997b) describing how to quantify ecological significance, the guidance calls for the use of professional judgment when describing the ecological significance of identified risks. The specific procedures used to evaluate ecological significance are presented in the BERA (Appendix G). Contaminants of ecological significance tended to meet the following criteria:

1. Had relatively high HQs in one or more environmental media.
2. Had potentially unacceptable ecological risks over extensive areas.
3. Spatial extent of potentially unacceptable risk encompassed many other contaminants that posed a risk at only one or a few locations in the Study Area.
4. Had potentially unacceptable risks to multiple ecological receptors.
5. Multiple LOEs indicated potentially unacceptable risks.
6. Known or has potential to biomagnify in food webs.
7. ~~Had an unusual (compared to other site chemicals) mode of toxic action.~~

These criteria help risk assessors make professional judgments about whether the potential adverse effects on organisms in the Study Area from exposure to contaminants pose risk to local populations, and whether those risks are ecologically significant.

The primary contaminants of ecological significance at Portland Harbor are PCBs, PAHs, dioxins and furans, and total DDx[5] (Table 9-7). EPA identified 16 additional contaminants of ~~secondary~~ ecological significance, as defined in Section 3.4.1 of the BERA, which are also ~~presented~~ listed in Table 9-7. Five of the 16 contaminants (cyanide, ethylbenzene, perchlorate, manganese and vanadium) are groundwater contaminants that only or primarily pose potentially unacceptable risks in transition zone

[5] Depending on the LOE, different TRVs are used for PCBs, PAHs, dioxins and furans, and total DDx, so different names are used to describe these chemical groups at different places in the BERA. For example, total DDx includes two individual chemical forms each of DDT, DDD, and DDE.

water, which is sediment porewater containing a mixture of groundwater and surface water.

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Table 9-7.Chemicals Identified as Most Likely to be Contaminants of Ecological Significance

Contaminants of Primary Ecological Significance	
PCBs	**Dioxins and furans**
PAHs	**DDT and its metabolites**
Additional Contaminants of ~~Secondary~~ Ecological Significance	
Total chlordanes	Mercury
Lead	Cadmium
Copper	BEHP
Zinc	Dieldrin
Lindane (γ-HCH)	Cyanide
Tributyltin	Ethylbenzene
Perchlorate	$C_{10} – C_{12}$ TPH
Manganese	Vanadium

Contaminants posing potentially unacceptable risk listed in Table 9-5 but not in Table 9-7 fall within low ecological significance levels. All contaminants posing potentially unacceptable risk at the end of the BERA (Table 9-7) were recommended to be carried forward to the FS. All other contaminants listed in Table 9-5 are recommended for comparison with projected post-remedial action conditions to confirm that alternatives developed for the ecologically significant contaminants would also be protective of risks of low ecological significance.

9.12 ECOLOGICAL RISK ASSESSMENT UNCERTAINTIES

By design, risk assessments are conservative in the face of uncertainty. In this context, conservative means efforts were made to minimize the chances of underestimating exposure, effects, or risk. The uncertainty analysis portions of the BERA are intended to illustrate the degree of confidence in the BERA conclusions. An uncertainty analysis can help the risk manager focus on those aspects of ecological risk that can be reduced during site remediation with the greatest certainty that the selected remedy will result in benefit to and the protection of the environment.

Uncertainty in a BERA has four components: variation, model uncertainty, decision rule uncertainty, and true unknowns. Examples of these types of uncertainty are:

- Variation - a fish is exposed to a range of contaminant concentrations in water, not to a constant concentration of a contaminant;

- Model uncertainty - use of a single species or several target ecological receptors within a feeding guild to represent all species within that guild introduces uncertainty because of the considerable amount of interspecies variability in sensitivity to a contaminant;

- Decision rule uncertainty - use of standard EPA default values, such as assuming contaminants are 100% bioavailable, because such defaults are used as single-point values throughout the BERA, despite having both variation and model uncertainty associated with them; and

- True unknowns - the effects of titanium in water on smallmouth bass survival, growth, and reproduction has never been studied and is unknown.

Consistent with the methods of the problem formulation (EPA 2008b), receptor-COPC pairs posing potentially unacceptable risk were identified using conservative methods and assumptions. Examples of conservatism include assumptions that environmental contaminant concentrations are 100% bioavailable and assumptions that resulted in low baseline TRVs, which, in the case of nutritionally essential metals such as copper, had to be adjusted upward because they were below nutritional requirements for some, but not all, fish species.

Not all uncertainties create a conservative bias. Some can lead to an underestimation of risk such as unavailability of exposure or effects data, thresholds that do not account for untested sensitive species, uncertainty about whether multiple COPCs present at the site interact synergistically, and uncertainty about whether metabolic processes increase the toxicity of accumulated contaminants in ways that are not observed in toxicity tests.

9.13 PRIMARY CONCLUSIONS OF THE BERA

Combining the findings of the BERA as summarized in Tables 9-4, 9-5, 9-6, and 9-7 and as described in more detail in the BERA, the following primary conclusions can be made.

- In total, 93 contaminants (as individual contaminants, sums, or totals) [6] with HQ ≥ 1 pose potentially unacceptable ecological risk. Differences in the specific TRVs used in different LOEs for total PCBs (e.g., total PCBs vs. specific Aroclor mixtures), total DDx, and total PAHs (17 individually measured contaminants such as naphthalene, as well as several groupings by molecular weight), all of which describe individual contaminants or a group of multiple but related individual chemical compounds, can result in different counts of the number of

[5] The five chemicals or chemical groups with concentrations that exceeded only the sediment probable effects concentration (PEC) and/or probable effects level (PEL) (i.e., chemicals that were not identified as COPCs for other benthic invertebrate LOEs: Aroclor 1254, chlordane [cis and trans], gamma-HCH [Lindane], heptachlor epoxide, and total chlordane), ammonia and sulfide (which are conventional parameters), and residual-range hydrocarbons that had concentrations that exceeded only the TPH SQVs are not included in this count.

contaminants posing potentially unacceptable risk. The list of contaminants posing potentially unacceptable risks can be condensed if all PCB, DDx and PAH compounds or groups are condensed into three comprehensive groups: total PCBs, total DDx, and total PAHs. Doing so reduces the number of contaminants with HQ ≥ 1 posing potentially unacceptable risks to 66.

- Risks to benthic invertebrates are clustered in 17 benthic areas of concern (AOCs).
- Sediment and TZW samples with the highest HQs for many contaminants also tend to be clustered in areas with the greatest benthic invertebrate toxicity.
- The COPCs in sediment that are most commonly spatially associated with locations of potentially unacceptable risk to the benthic community or populations are PAHs and DDx compounds.
- Not all COPCs posing potentially unacceptable risk have equal ecological significance. The most ecologically significant COPCs are PCBs, PAHs, dioxins and furans, and DDT and its metabolites.
- The list of ecologically significant COPCs is not intended to suggest that other contaminants in the Study Area do not also present potentially unacceptable risk.
- The contaminants identified as posing potentially unacceptable risk in the largest numbers of LOEs are (in decreasing frequency of occurrence) total PCBs, copper, total DDx, lead, tributyltin (TBT), zinc, total toxic equivalent (TEQ), PCB TEQ, benzo(a)pyrene, cadmium, 4,4′-DDT, dioxin/furan TEQ, bis(2-ethylhexyl) phthalate (BEHP), naphthalene, and benzo(a)anthracene. The remaining 78 contaminants posing potentially unacceptable risk were identified as posing potentially unacceptable risk by three or fewer LOEs.
- Of the three groups of contaminants (i.e., total PAHs, total PCBs, total DDx) with the greatest areal extent of HQs ≥ 1.0 in the Study Area, PAH and DDx risks are largely limited to benthic invertebrates and other sediment-associated receptors. PCBs tend to pose their largest ecological risks to mammals and birds.
- The combined toxicity of dioxins/furans and dioxin-like PCBs, expressed as total TEQ, poses the potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle, and osprey. The PCB TEQ fraction of the total TEQ is responsible for the majority of total TEQ exposure, but the total dioxin/furan TEQ fraction also exceeds its TRV in some locations of the Study Area.